Rijkswaterstaat
Ministry of Transport, Public Works and Water Management

A brief history of inland navigation and waterways

the development of the waterway infrastructure in the Netherlands

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Published by	RWS Centre for Transport and Navigation (DVS)
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1 Introduction

This document briefly describes the development of the waterways and inland navigation from the beginning of the common era to the late twentieth century. It looks not only at commercial shipping but also at recreational navigation. The main emphasis is on developments in the Netherlands in the nineteenth and twentieth centuries. Since inland navigation is a highly international affair, however, we shall also take a look beyond the Netherlands' borders.

The report looks at the history of inland navigation vessels and the waterways along which they travel. There is a great deal of interaction between the two. Waterways have to be adapted to certain types of vessel, and vessels are designed on the basis of what a particular waterway has to offer. So it's a chicken and egg situation. I have opted to start with the waterways, and then turn my attention to the vessels themselves. Each chapter is summarised in a number of bullet points at the end.

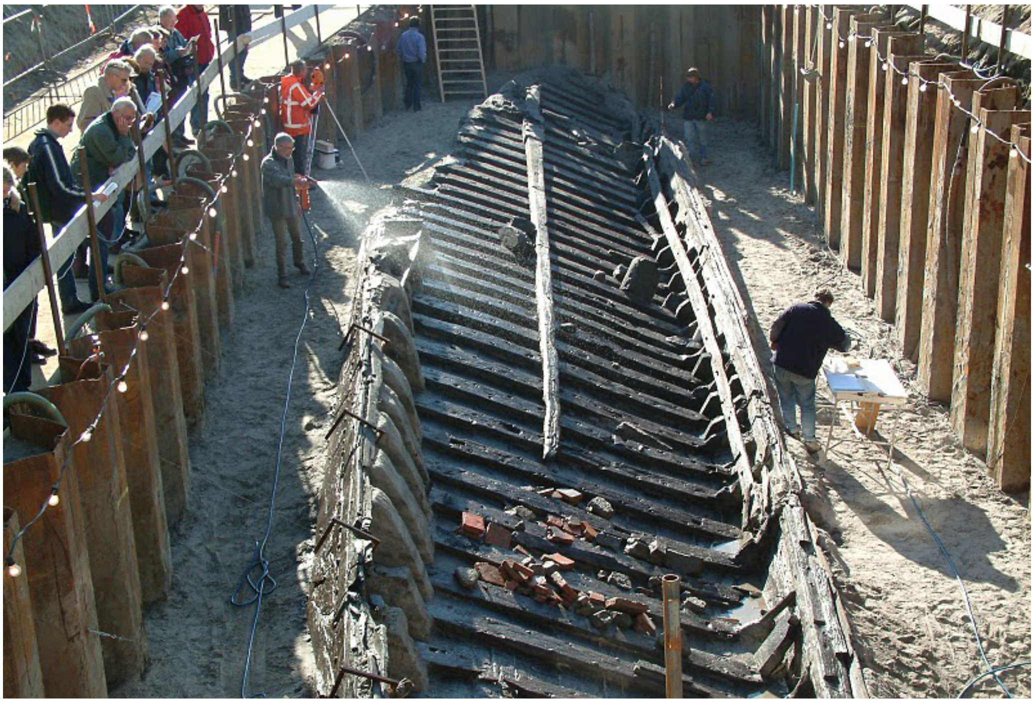
What follows is only a brief account, particularly as far as the waterways are concerned. It is far from complete, and is more of an introduction to the subject than a definitive history.

Dr. J.U. Brolsma

2 Waterways and networks

2.1 Development prior to 1800

The Romans were the first to build waterways in the Netherlands.
Around the beginning of the common era, they designated the Rhine – at least, what is known today as the Oude Rijn – the northern border of their empire.
To allow them to move their troops around quickly, they built the Corbulo and Drusus canals. The Corbulo canal, or Fossa Corbulo, linked the Maas and Rhine rivers behind the coastal dunes. Excavations have shown that this waterway was some 13 m wide and 2 to 3 m deep at Voorburg. In the east of the country, the Drusus canal linked the Rhine and the Gelderse IJssel.
Its precise route is unknown.



1 Excavation of a Roman ship beside the Oude Rijn river

It was Charlemagne who first had the idea of connecting the North Sea and the Black Sea. In AD 793 he ordered the construction of the Fossa Carolina, a connection between the Rhine and Danube river catchments. In the aptly-named southern German village of Graben (literally, ‘to dig’), an excavation some three kilometres in length can be seen. The project progressed no further, however. Charlemagne’s plan far exceeded the technology of the time. Shipping here and elsewhere in Europe used the many natural watercourses, including very modest rivers like the Regge, the Dinkel and the Belgian Ourthe. Waterways were sometimes dug locally, mainly as fairly short connections between two natural watercourses. In 1253, for example, a lock with mitre gates was constructed at Spaarndam to divide the river Spaarne from the river IJ, and prevent flooding. When it received its city charter in 1340, Rotterdam was given permission to dig a connection between the city and the Schie, and in 1390 Delft had a canal dug to connect Overschie and Delfshaven.

In the southern Netherlands, which was more economically advanced than the northern Republic, various canals were dug in the sixteenth and seventeenth centuries. In 1561, for example, a 30 km canal between Brussels and the river Rupel was completed, connecting the city with the river Scheldt. The first horse-drawn barge service in the Low Countries was established here in 1618. The Sassevaart canal was also commissioned in 1561, directly connecting Ghent with the Western Scheldt; it was superseded by the Ghent-Bruges Canal in 1623. Under the 1648 Peace of Münster the new Republic of the United Provinces gained Zeeland-Flanders, and took advantage of this opportunity to block the Western Scheldt. The Ghent-Bruges Canal therefore had to serve as the Belgian's access route to the sea for the next 150 years.

2 A horse-drawn barge: the 'trekschuit' (R. Nooms, appr. 1650)

The seventeenth century – known in the Netherlands as the 'Golden Age' – was a time of great economic prosperity. Growing wealth caused a rising demand for mobility. In the period between 1632 and 1665 a 658 km system of canals for pulled barges was created at the instigation of city councils and private investors. Passenger services connected 39 towns and cities. Where horse-drawn barges could not be used, as on the Zuyder Zee and in the waters of the delta, regular ferry services were introduced. Sometimes no new waterway needed to be dug, and it was enough simply to create a towpath along an existing waterway. The fixed, pre-published timetable and fixed prices were particularly innovative. The connections were interlocal, and central government had no role either in instigating or in managing them. The barges were 10 to 15 m long and could carry 20 to 30 passengers. The horse-drawn barge was reliable, cheap and fairly fast for its time. This mode of transport was used for over two hundred years, until it was eventually displaced by the much faster steam train.

A major French achievement of the seventeenth century was the Canal du Midi, connecting the Mediterranean and the Atlantic, built between 1667 and 1681 on the orders of Louis XIV. The 240 km canal had 101 locks with an average lift of 2.5 m, several aqueducts, tunnels and a number of imposing flights of locks. The watershed is 190 m above sea level. The water supply to the watershed involved several magnificent feats of engineering to reroute a number of small rivers and create artificial reservoirs. Today the canal is used exclusively for recreation. The highpoint of French canal building was achieved in the following century, however.

3 Anderton Boat Lift on the Trent and Mersey Canal, built in 1875

The Industrial Revolution in the eighteenth century prompted the start of ‘canal mania’ in Britain. Only water could cheaply transport the raw materials vital for industry. The standard dimensions of British canals and engineering works were based on the narrow boat, which was originally seven foot wide, though some later models were 14 foot wide. They could carry up to 60 tons. The privately funded canals were initially highly profitable, inspiring more and more canal projects. Between 1761 (the opening of the Bridgewater Canal, the first in the country) and 1830, a network of more than 4000 km of canals and canalised rivers was created in England and Wales, which in its heyday transported 30 millions tons of freight a year. The canals of Britain truly showcase the technology of their age: tunnels several kilometres long, aqueducts, boat lifts, staircase locks and ingeniously designed bridges. After 1830, however, the canals could no longer compete with the railways. Investment dried up and the network fell into decline. Over the past few decades, many canals have been restored for recreational use.

2.2 Nineteenth century in the Netherlands

The nineteenth century was a period of radical political and technological change. After the defeat of Napoleon the allies decided to merge the Netherlands and Belgium into one kingdom, and to make the Rhine an international, toll-free river. This was officially confirmed in the 1868 Convention of Mannheim. The Central Commission for Navigation on the Rhine (CCNR), established in Strasbourg, was given the task of guaranteeing the free, safe navigation of the Rhine.
King William I tried to forge a single nation of the Netherlands and Belgium by building canals, particularly in the period 1815-1830. It is likely he was inspired by the canals of Britain during his time in exile there. Canals built in this period include the Willemsvaart (Groningen-Assen), the Zederik Canal (Amsterdam-Rhine), the Apeldoorn Canal, the Zuid-Willemsvaart (as an alternative to the unreliable river Maas), as well as several canals in Belgium, including the Brussels-Charleroi Canal which played a particularly important role in transporting coal. At the same time, as

sailing boats increased in size, access to sea ports became problematic. William I insisted on the construction of the Groot Noord-Hollandsch Kanaal (the 'Great North-Holland Canal'), the Kanaal door Voorne ('Canal through Voorne') and the Ghent-Terneuzen Canal, to provide access to the ports of Amsterdam, Rotterdam and Ghent. This last connection was opened in 1827, but closed again in 1830 in response to the Belgian Revolution.

4 Apeldoorn Canal

The Groot Noord-Hollandsch Kanaal and the Kanaal door Voorne soon turned out to be too narrow for sea-going vessels, which continued to grow in size. They were therefore replaced by the North Sea Canal and the Nieuwe Waterweg ('New Waterway'), which opened in 1872.

In 1850 the government decided to normalise the river Waal. In other words, the cross section was secured using groynes and training dams. Work on the river continued until 1916. The primary goal was to prevent flooding, but a not unimportant side effect of the work was to create a more easily navigable route between Rotterdam and the industrialising German hinterland. The nineteenth century saw the advent of steam power, and of steel for construction. In the water-rich delta region, in particular, where there was no competition from the railways, a network of steam passenger services developed. Thanks to steam tow boats, cargo vessels were no longer at the mercy of the wind and water, and thus led to a huge rise in productivity. Navigation flourished on the Rhine and the inland waterways. Large-scale peat cutting in the north of the country began in the seventeenth century and continued into the twentieth, when it became unnecessary thanks to the availability of coal, oil and, later, natural gas. Many canals were dug to drain the peat and make it accessible, including the Winschoterdiep, Stadskanaal, Musselkanaal, Hoogeveense Vaart, Oranjekanaal and many small auxiliary canals. Sailing barges transported the peat to market elsewhere in the country, where the bargemen generally sold it themselves.

5 Old branch of the Zuid-Willemsvaart near Helmond, with a Kempenaar type barge

The Netherlands’ industrial revolution took place in the second half of the nineteenth century. The growth in freight transport meant new canals had to be built. They included the Eemskanaal, the Overijssel canals, and the canals through Zuid-Beveland and Walcheren. The construction of the 71 km Merwede Canal, opened in 1892, gave Amsterdam a better link to the Rhine. The locks, measuring 120 x 12 x 13.1 m, were dimensioned to accommodate a tow boat with four towed barges. The locks soon turned out be too small, however, which led to long delays.

6 River Waal near Nijmegen

2.3 Nineteenth century in other countries

I have already mentioned Charlemagne's plan for connecting the Main and Danube.
It was Ludwig I of Bavaria who actually managed to achieve this dream.
In 1836, work commenced on a 172 km canal with 101 locks for ships of 100 tons, which was completed in 1845. In its heyday, in 1850, the canal carried 196,000 tons of freight. But the canals soon began to suffer from the competition offered by the railways. Use of the canal decline further due to a shortage of water, formation of ice and shallows in the connecting Main and Danube.
Some remains of the narrow Ludwig Canal can still be seen near the present-day Main-Danube Canal.

7 Remains of a lock on the former Ludwigs Canal

The Franco-Prussian war of 1870-1871 provided an embarrassing illustration of the inability of the waterways to provide good logistical services because of their non-standard dimensions. In response, in 1879 the French minister of public works, Charles de Freycinet, launched a new law for the improvement of 7600 km of rivers and canals, and the construction of a further 1400 km of canals. The act stipulated standard dimensions for locks: 38.5 x 5.2 m for a permissible draft of 1.8 m, and clearance of 3.7 m. This made the péniche, with a carrying capacity of 300 tons, the standard on the French canal system.
Though the programme was never completed, in 1892, 15 years after the law was passed, 4100 km of canal conformed to the new standard dimensions.
By 1913, just before the outbreak of the First World War, the capacity of the inland navigation system was double what it had been in 1890.

The unification of Germany in 1871 greatly boosted the expansion of the German waterways network. Conditions on the rivers Rhine, Main, Neckar, Elbe and Oder continually improved. Basle eventually became accessible by water in 1904. The new German state pursued a deliberate policy of expanding the network of waterways and improving the accessibility of its sea ports.

8 Two péniches on the Canal du Nord in France

Plans for the construction of the Dortmund-Eems Canal were approved in 1886, with the aim of connecting the Ruhrgebiet with the sea. The 270 km canal was completed in 1899. The design had initially been based on a 600-ton tow barge, but it was decided during the construction work that 1000 tons should be adopted as the standard. The Oder-Spree Canal made Berlin accessible to 500-ton barges, mostly laden with coal from Silesia. Other German canals were completed after the turn of the century.
Finally, the Kiel Canal should be mentioned, which was built between 1887 and 1895. It was intended for seagoing vessels, and was important from a military point of view, since German warships could now travel from the North Sea to the Baltic through their own territory, unobserved and unhindered.

It would not be possible to mention all the waterways built in the nineteenth century, but two cannot be overlooked: the Suez Canal, opened in 1869; followed in 1914 by the opening of another major waterway: the Panama Canal.

2.4 Twentieth century

The twentieth century saw a sharp turn in the tide. In economic terms, the initial years of the new century represented a continuation of the previous one.
Then came the First World War, followed by a brief economic revival and then the Great Depression of the 1930s, the Second World War and the Cold War. Finally, there was a huge growth in prosperity in the 1960s.
The first motorised vessels came into use in the early twentieth century.
After the Second World War steam ships were rapidly replaced by motorised ships, and the last wooden sailing ships disappeared. This all led to a major expansion in scale, particularly after push barges were introduced in 1957.
Radar made it possible to continue navigating through the night, and the advent of the container opened up a new market for inland navigation.
During the course of the twentieth century inland navigation experienced growing

competition from road freight. As a result, scheduled services that transported packages and freight disappeared. Commercial navigation focused henceforth on mass transport. At the same time, prosperity was on the increase, and more and more people could afford their own leisure craft. Recreational navigation flourished and small waterways that were no longer suitable for goods transport attracted new customers, particularly in countries like France and Britain, and also in the Netherlands. Old canals were refurbished and reopened to leisure craft.

9 Amsterdam-Rhine Canal

In the interwar period several canals were built, including the Wilhelmina Canal, the Wessem-Nederweert Canal, the Maas-Waal Canal, the canals of Twente and the Juliana Canal. This last waterway was essential for the transport of coal from Limburg's mines. The Maas became a reliably navigable route thanks to canalisation. The Merwede Canal was no longer fit for purpose, and in 1931 it was decided that the Amsterdam-Rhine Canal should be built. After delays caused by the economic crisis and the war, it was finally completed in 1952. For the sake of the water supply, three locks with adjacent weirs were built in the Beneden-Rijn river. After years of pleading, Antwerp finally got an adequate connection to the Rhine in the form of the Scheldt-Rhine Canal. And the Delta project meant that the Kanaal door Zuid-Beveland had to be widened. The port of Rotterdam was given its own separate connection to the inland waterway network in the form of the Hartel Canal. The first traffic control centres appeared along the waterways, improving speed and safety on dangerous sections. Apart from a number of plans to widen certain sections and increase the capacity of certain locks, the Dutch waterways would appear to be 'finished'. The only new canal planned is the diversion of the Zuid-Willemsvaart east of Den Bosch, by no more than 10 km, to replace the narrow Den Bosch traverse.

Germany completed a number of important canals in the early twentieth century, including the Rhine-Herne Canal which connects the industrial city of Dortmund with the Rhine, the Mittelland Canal that runs from the west of the country to Berlin,

and several canals linking Berlin and the Oder. Rivers like the Neckar, Mosel and Saar have been made more accessible to shipping thanks to the construction of locks.

In 1926 work began on a new connection between the Rhine and the Danube, the first step of which was to canalise 297 km of the river Main and 209 km of the Danube in Germany. The actual Main-Danube Canal between Bamberg and Kelheim is 171 km long. Between the watershed and Bamburg, it covers a difference in elevation of 175 m with a total of 16 locks, the largest of which have a lift of 24.7 m. The canal opened in 1992. German reunification prompted a major inland navigation project to improve the connection between the Mittellandkanal at Magdeburg and Berlin. As part of this project, an aqueduct more than 900 m long was built to take the canal over the river Elbe.
The trough is 32 m wide, enough only for one-way traffic. Work continues to widen the 100 km Elbe-Havel Canal.

10 Volkerak Locks in the Scheldt-Rhine Canal

The navigability of the Danube in Austria has been significantly improved by the construction of several sets of locks, combined with electricity generating plants. The last to be completed was the dam at Freudenau near Vienna, in 1998.
The main improvement was already completed a century earlier, however, with the Iron Gate locks where the Danube cuts through the Carpathian mountains, which produce a lift of 26 m over 11 km. Nevertheless, shipping on the Danube, which is much less predictable than the Rhine, is still adversely affected by shallows in Germany, Austria and Hungary during periods when the water level is low.
There is no prospect of a speedy solution to this problem. The environmental movement is strongly opposed to any intervention in the riverbed, and their campaigns have proved successful so far. Transport via the Danube will continue to lag far behind that on the Rhine for some time to come.

11 Elbe aqueduct near Magdeburg

The most extensive and, in a certain way, the most curious network in Europe is in Russia. The countries of the former Soviet Union have more than 400,000 km of waterways, including a 6300 km system of deep waterways in the European part of Russia, linking the Baltic, the White Sea, the Black Sea and the Caspian Sea. The permissible draft is 3.5 to 4.0 m. It was Tsar Peter the Great who started canal building in Russia, with the idea of linking the great rivers. Another dictator, Stalin, completed his work. Three key connections were built during his regime: the Baltic Canal, the Moscow-Volga Canal and the Volga-Don Canal.

12 Princess Margriet lock at Lemmer has a ‘green lock chamber’

The Baltic Canal, or Byelomorsk-Baltic Canal as the Russians call it, runs from Lake Onega to the White Sea. It is estimated that 250,000 forced labourers died during its construction. The canal, which opened in 1933, conquers a difference in elevation of 108 m relative to sea level, with a total of 19 locks measuring 130 x 14 x 4 m. It is frozen over every year from November to May. The 128 km Moscow-Volga Canal was partly built by forced labourers, too, and in 1937 gave Moscow its long-coveted link to the Baltic. The pinnacle of Stalin's canal building is the Volga-Danube Canal, work on which lasted from 1938 to 1952, a year before the leader's death. It is 101 km long and has 13 locks measuring 145 x 17.8 x 4.0 m.
According to a United Nations study, in mid-1993 the European waterway network, including the European part of the Russian Federation, was 77,845 km long. Of that, 25,302 km is of 'international importance', which means that it is suitable for or has been nominated for upgrading to accommodate shipping of at least Class IV, with approximately 1500 tons' capacity.

13 Princesse Beatrix Lock in the Amsterdam-Rhine Canal

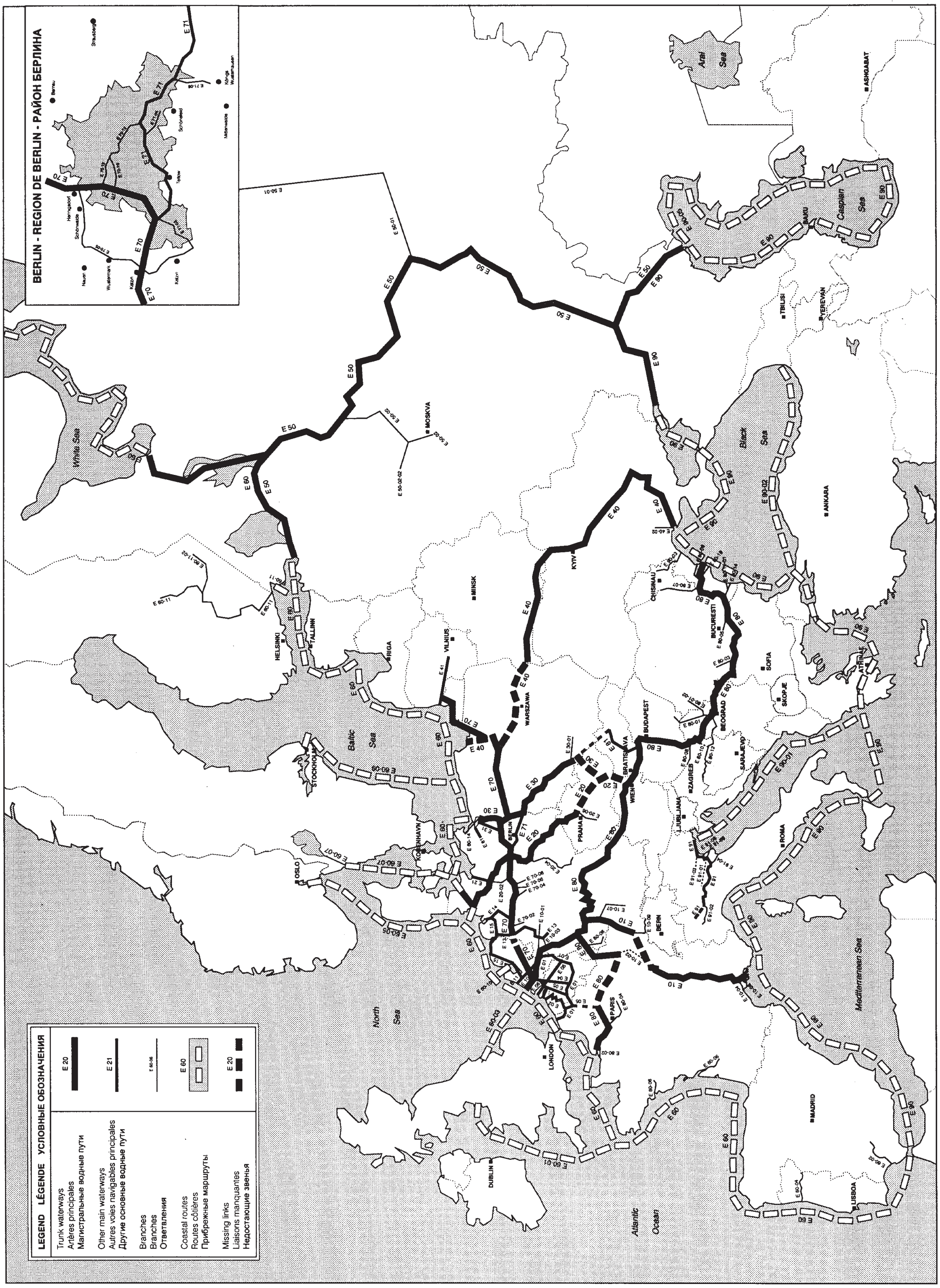


Figure 1: Map of the European Waterway Network according to the ECE

2.5 European networks

In theory there are two European networks which, though very similar, are not entirely the same. One has been defined by the European Union (EU), the other by the Economic Commission for Europe (ECE), a UN agency established in Geneva. The EU is smaller than the area covered by the ECE, so the ECE network is more comprehensive.

The EU network was officially defined by the Council on 29 October 1993. On the same day, the Council also approved a Trans-European Combined Transport Network, consisting of road, rail and waterway connections for container transport. The waterways mentioned are all part of the Trans-European Inland Waterway Network. The Council decided that the network must comply with at least CEMT Class IV and, if it were modernised, it would have to be suitable for upgrading to Class Va/Vb, to accommodate combined transport shipping (i.e. container transport). The defined network can be regarded as indicative, a measure for promoting development, with no financial obligations or commitments. Nevertheless, it was stipulated that within ten years the member states would have to develop initiatives to tackle ten bottlenecks and missing links. There are no penalties for failing to do so, however.

14 Narrowing due to sand accretion in a bend on the Danube

The Economic Commission for Europe, known at the ECE for short, drafted the European Agreement on Main Inland Waterways of International Importance (AGN). The AGN was signed by eleven European countries, including the Netherlands, in June 1997. The Group of Experts who prepared the agreement not only established a network (see page ..), they also numbered the waterways and defined their operational and technical specifications. The AGN's goal for the main waterways is Class Vb with 2.8 m draft. Countries that sign the AGN adopt this specification as a guideline for the development, construction and operation of their national waterways. The AGN does not stipulate a deadline for completion of the plan, imposes no financial obligations and cannot bring any legal pressure to bear, but its

signatories are under a moral obligation.
There are some bottlenecks and missing links in the E-network. Old plans, most of them drawn up for nationalistic or strategic (= military) reasons, have proved resilient and the rather theoretical approach of the Group of Experts has meant that old feelings have been aroused by the AGN. In this respect, the EU's approach, with a list of problems that need to be tackled, is more realistic. One bottleneck that appears to be almost resolved is the connection between the Seine and Scheldt basins: the Canal Seine Nord-Europe. The two main European bottlenecks are currently the Magdeburg-Berlin connection (due to narrowing) and the Straubing-Vilshofen stretch of the Danube in Germany (shallows).

2.6 The Netherlands' main waterway network

Policy on the Netherlands' main waterway network is set out in the Policy Document on Mobility 2004. The document's main conclusions on the network are:

- there are three types of waterway: trunk waterways (550 km), main waterways (900 km) and other waterways (5200 km)
- central government's priority is the main waterways
- preservation before construction, i.e. bringing maintenance up to standard is more important than building new waterways
- reliable journey times are a key focus of policy
- the government will foster innovation

Trunk waterways carry more than five million tons of international freight a year and/or 25,000 TEUs (20-foot containers). The trunk waterways connect the sea ports of Amsterdam, Rotterdam, Ghent and Antwerp with the Rhine. Main waterways meet the same criteria, but then for domestic transport. Figure 2 shows the network.

Trunk waterways can take four-barge push tows (Class VIb) and shipping with four layers of containers. Other main waterways are suitable for shipping of at least 1500 tons (Class IV) and shipping with three layers of containers. The policy focus of reliable journey times is achieved through a number of measures:

- waterways comply with the agreed dimensions, in accordance with the Dutch Waterway Guidelines
- avoidance of discontinuity both in the cross section of the waterway and in service times
- sufficient availability, achieved by, among other things, well-considered maintenance schedules, and use of ice-breakers in winter if necessary
- sufficient lock capacity thanks to timely measures
- enough overnight berths, so that bargemen can comply with statutory rest periods
- measures to foster smooth, safe traffic, including the implementation of River Information Services (electronic sea charts, automatic vessel identification, standardised messaging etc.)

Details of the implementation and costs of such measures can be found in the MIRT project book, issued each year as an appendix to the budget. MIRT is an acronym based on the Dutch for Multi-year Infrastructure, Spatial Development and Transport Programme.

Figure 2: The Netherlands' main waterway network

2.7 Waterways in a nutshell

Reviewing the history of the waterways outlined above, the key points in the development of the Netherlands' waterways are:

- the Romans were the first to build canals in this country, around the beginning of the common era
- until the seventeenth century, waterways were mostly natural features
- seventeenth century: a network of barge canals was constructed
- eighteenth century: major canal building projects in the UK and France, very little development in the Netherlands
- nineteenth century: major government involvement, encouraged by King William I, construction of canals like the Zederik Canal, Zuid-Willemsvaart, North Sea Canal, Nieuwe Waterweg
- twentieth century: creation of large modern waterways like the Juliana Canal, the Amsterdam-Rhine Canal, the Hartel Canal and the Scheldt-Rhine Canal

15 Sas van Gent Bridge over the Ghent-Terneuzen Canal

3 Development of inland navigation vessels

3.1 Sailing vessels

For centuries, shipping was synonymous with sailing, both at sea and on inland waterways. Inland vessels came in all shapes and sizes, depending on what they were used for and where. They included the smak ~~(smack)~~, tjalk, snik, praam, poon etc. Virtually the only waterways were natural, shallow watercourses. The Rotterdam port ordinance of 1657, for example, stipulated that vessels with a draft of more than ten foot (three metres) must anchor in the Nieuwe Maas, because the port basins could not accommodate them.
Inland shipping vessels were mainly flat-bottomed barges with leeboards to keep them on course. Wooden rafts were a common sight on the Rhine and its tributaries until the early twentieth century. They were carried along by the current or were towed – only downstream, of course. If there was no wind, or the wind was blowing in the wrong direction, the crew had to row, punt, or wait for the wind to change. Tow barges with passengers were pulled by one or sometimes two horses, cargo boats were often pulled by their own crew, or the bargeman's family. Progress was slow, and highly inefficient to our modern way of thinking, but in comparison with transport over land, the productivity of water transport was still considerably higher. In the Netherlands, with its many waterways, water was for a long time the most logical and predominant mode of transport.

16 Sailing boats were used on inland waterways until after the Second World War

3.2 Steam and steel

The first steam ship – the Defiance – was seen on Dutch waters in 1816, on its way from Britain to Cologne. Conservative forces were dismissive, but King William I saw its potential. He wanted to bring the northern and southern Low Countries closer together, and one of the ways of doing that was a fast connection over land between

Amsterdam and Brussels. But the main obstacle was Hollands Diep. In 1822 a steamboat began to operate a ferry service across it, which could make the crossing virtually irrespective of the wind and current. And, in response to the King's fervent wishes, Rotterdam city council established a steam ferry service on the Katendrechtse Veer in 1824. In the years that followed, travel by steam ship gradually took off. In 1826 the Köln-Düsseldorfer Rhinschiffahrt AG began regular passenger services on the Rhine in Germany. Here in the Netherlands a network of passenger steamboats was created on rivers and sea inlets. Many of these services went out of business in the second half of the nineteenth century, unable to cope with competition from the railways.

17 Steam tug with side paddle wheels on the Rhine

In 1832 a steam tow boat service was established on the Waal, with government support. In 1841 the first steel Rijnaak appeared on the Rhine. The two turned out to be a fortunate combination, and they soon defined the look of shipping on the Rhine and inland waterways. It seemed that inland vessels would be able to win back some of the ground they had lost to freight transport by rail. The transport of coal exports from Germany to Rotterdam was initially all by train, for example. As the normalisation of the Waal progressed, providing better conditions for shipping, the Rijnaak turned out to be a cheaper alternative and, after the turn of the century, transport by water won out over rail. The same happened with the transport of petroleum, which was initially carried in barrels by rail. When the first river tankers appeared in the late nineteenth century, the dominance of rail soon came to an end. In the second half of the twentieth century tankers would again lose a large proportion of their cargo to pipelines, however. Steam and steel brought a huge improvement to the efficiency of inland shipping. They were first used on the Rhine, while wooden sailing barges would continue to be used on smaller canals until after the Second World War. By that time, the next improvement in efficiency had arrived: the internal combustion engine.

3.3 Motorisation

The internal combustion engine was invented in the late nineteenth century and in 1893 Rudolf Diesel patented the engine that bears his name. The breakthrough in motorisation for inland shipping did not occur until after the First World War, however. It offered major advantages over steam, which was laborious. The boiler had to be heated long before the journey commenced and it had to be kept up to temperature. A driver and a stoker were needed, the bunker had to be filled with coal and the ash had to be shovelled out. The bunker, boiler and engine took a lot of space, and steam engines consumed more fuel than the internal combustion engine. There was initially one drawback to steam's replacement, however: internal combustion engines were expensive. The first to be used in inland navigation were on luxury motorised vessels used for scheduled local services, carrying parcels and freight between towns and cities. This was the first sector to be hit by competition from trucks, a battle which, despite the combustion engine, it would lose. Before the Second World War sailing and tow boats would be fitted with a separate side propeller, known as a 'lame arm'. The engine was on the foredeck and the propeller shaft was lowered into the water alongside the hull. The next step was the pusher tug, a small motorised sloop that was attached close to the stern. The main vessel would steer, as always. This meant sailing barges and tow barges could operate without a tow boat, representing another major improvement in efficiency. In 1956, for the first time, the number of motorised barges exceeded the number of tow barges. Nowadays, tow barges have all but disappeared.

The next breakthrough was radar, which had been invented shortly before the Second World War. It was first used in sea shipping just after the war. Affordable radars for inland shipping would not become available until the 1960s. Prior to that, travelling at night and in mist and fog was difficult, if not impossible. With a radar, the bargeman always has a view of his surroundings, allowing him to continue his journey safely. Only heavy rainfall or snow disrupt radar. A barge with a radar is also obliged to have a mobile radio telephone on board, to make navigational arrangements directly with other barges or via a traffic control post. Bargemen must have a radar endorsement licence.

One major innovation of the past few decades has been the bow thruster. This small propeller positioned transversally in the forward part of the vessel makes mooring a much easier and quicker process. This is particularly important for vessels with a large longitudinal surface area, like container barges. Bow thrusters are now a standard feature on cargo vessels, which rely on diesel engines for forward propulsion, radar for when visibility is poor and a bow thruster to assist manoeuvres.

3.4 Standardised dimensions

In 1954 the Conférence Européenne des Ministres de Transports (CEMT) established an international classification system dividing waterways into five classes, depending on their dimensions. The basis of the system was the dimensions of five types of vessel, most of them towed, which were common in Western Europe at the time. A waterway's class is determined by the largest standard vessel it can accommodate. The width is the main determining factor. The CEMT recommended that Class IV vessels continued to be used as the standard for waterways of European importance.

The first convoy of push barges travelled along the Rhine in 1957. The system soon took off. The CEMT responded in 1961 by added Class VI to its classification. However, after a while, this classification also became inadequate. PIANC, the international association for waterborne infrastructure, took the lead when the system was reviewed. This led to a new, uniform classification drawn up by the

CEMT and the UN's Economic Commission for Europe (ECE), known as CEMT1992 after the year in which it was published. The new classification takes account of East European waterways, which are generally slightly smaller than similar waterways in Western Europe. Table 1 (page ..) shows only the dimensions relevant to Western Europe, i.e. to the west of the Elbe. Vessels from the former Eastern Bloc tend to be wider on the whole, as they use waterways with a limited draft. Such vessels are very rare in the Netherlands.
Several footnotes have been added to the original CEMT table. For example, when two values are given, the first figure refers to the existing situation, and the second indicates the situation in the future. However, two existing situations might also be indicated. So it's pretty confusing. The figure for the minimum bridge clearance includes a safety margin of 0.30 m between the highest point of the barge and the bottom of the bridge in the event of standard high water levels. This margin is intended to compensate for errors of judgment and unexpected fluctuations in the water level.
The dimensions for Class VI motorised vessels were based on assumed future developments in RoRo, container and sea/river vessels. It now appears that a width of 17.0 m is more realistic than 15.0 m. The draft for a particular waterway has to be determined on the basis of local conditions. The principle is that 50% of standard vessels should be able to use the waterway, complying with the draft restrictions.
A thorough analysis of the dimension of vessels has shown that the figures in the CEMT table no longer represent the fleet of inland navigation vessels operating in this country. This applies particularly to vessels in Class III and higher. Because vessels have grown longer and longer, the standard length has increased relative to the standard width. The draft of Dutch vessels is also often larger than that used by the CEMT, because waterways in the low countries can take vessels with a larger draft than canals in Central Europe. The tonnage restrictions therefore differ from the figures in the CEMT table. The choice of Class IV vessels as the European standard is also outmoded, and Class V is now more representative of the current fleet. This issue is explored further in section 3.7, which looks at scale expansion.

18 Class Va vessel (110 x 11.4 m), the current standard

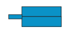
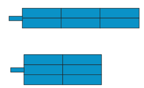
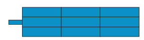
Type de voies navigables / Type of Inland waterways	Classe de voies navigables / Classes of navigables waterways	Automoteurs et chalands / Motor vessels and barges — Type de bateaux: caractéristiques générales / Type of vessel: générales characteristics					Convois poussés / Pushed convoys — Type de convoi- Caractéristiques générales / Type of convoy- Générales characteristics					Hauteur minimale sous les ponts / Minimum height under bridges
		Dénomination / Designation	Longueur / Length	Largeur / Beam	Tirant déau / Draught	Tonnage / Tonnage		Longueur / Length	Largeur / Beam	Tirant déau / Draught	Tonnage / Tonnage	
			m	m	m	t		m	m	m	t	m
D'INTERET REGIONAL / OF REGIONAL IMPORTANCE	I	Péniche / Barge	38.50	5.05	1.80-2.20	250-400						4.00
	II	Kast-Caminois / Campine-Barge	50-55	6.60	2.50	4.00-650						4.00-5.00
	III	Gustav Koenings	67-80	8.20	2.50	650-1000						4.00-5.00
D'INTERET INTERNATIONAL / OF INTERNATIONAL IMPORTANCE	IV	Johan Welker	80-85	9.50	2.50	1000-1500		85	9.50	2.50-2.80	1250-1450	5.25/or 7.00
	Va	Grand bateaux Rhenands/Large Rhine Vessels	95-110	11.40	2.50-2.80	1500-3000		95-110	11.40	2.50-4.50	1600-3000	5.25/or 7.00/or 9.10
	Vb							172-185	11.40	2.50-4.50	3200-6000	
	VIa							95-110	22.80	2.50-4.50	3200-6000	7.10/or 9.10
	VIb		140	15.00	3.90			185-195	22.80	2.50-4.50	6400-12000	7.10/or 9.10
	VIc							270-280 193-200	22.80 33.00-34.20	2.50-4.50 2.50-4.50	9600-18000	9.10
	VII							285 195	33.00 34.20	2.50-4.50	14500-27000	9.10

Table 1: CEMT classification from 1992 for waterways west of the Elbe

19 Convoy of push barges, with six barges in long formation

3.5 Push towing

After the Second World War, the economy grew rapidly, and so did the demand for transport. Classic tow barges could not offer sufficient capacity, and rising wages caused freight costs to increase. In 1953 a mission from the French state shipping company visited the United States to study the phenomenon of push towing. When the paddle steamers that sailed the Mississippi wanted to take along extra lighters, they could only do so by placing them in front of the boat, and so the concept of push towing emerged. In response to the visit, it was decided in 1957 that the method should be trialled on the Rhine using the converted tugboat President Herrenschmidt. The trial was highly successful, and the French had more vessels converted. By now, a combination of two Dutch and two German shipping companies had also conducted a study and commissioned a real push barge. On 21 October 1957 the 1250 horsepower Wasserbüffel made its maiden voyage with four barges of 1250 tons each. Push barges brought about a huge increase in productivity: by a factor five per crew member on the shuttle service between Rotterdam and the Ruhrgebiet. The move from towing to push barges was completed in just a few years. On the biggest waterways, combinations with four Europa IIa barges are permitted and, in certain circumstances, combinations with six Europa IIa barges may navigate the Rhine.

CEMT Class	**type of push barge**	**width (m)**	**length (m)**	**draft when loaded**	**carrying capacity (tons)**
IV	Europa I	9.5	70.0	3.0	1450
Va	Europa II	11.4	76.5	3.5	2450
Va	Europa IIa	11.4	76.5	4.0	2780

Table 2: Characteristics of standard push barges

After a time, certain standard measurements emerged for push barges. The Europa II type is the most common, but there are other standard push barges. The main types are listed in table 2. The width of these barges is generally the same as motorised vessels in the same class. No standard measurements can be given for push boats, not least because many small push boats are in fact converted tow boats. In view of the maximum permissible length for push barge combinations on the Rhine, the heaviest type of push boat is some 40 m long and approx. 15 m wide.

3.6 Container ships

The main development over the past few decades has been the rapid rise of container transport. The first transatlantic container arrived in Rotterdam in 1966 to continue its journey by truck. Containers were expensive, after all, and rapid transport by land was the only option, or so it was thought. An inland vessel would be used to transport a container as deck cargo only as an exception. The more common containers became, and the more the importance of low transport costs came to prevail over the speed of transport to the final destination, the more ground inland navigation gained. The first scheduled service began on the Rhine in 1974, and in 1987 Nijmegen opened the first inland container terminal in the Netherlands. Figure 2 illustrates what was until recently a rapid rise in the transport of containers by inland vessels. The number of containers is expressed in units of 20 foot, known as twenty foot equivalent units, abbreviated to TEU. The Kreekrak Locks can be regarded as representative of international transport, the Princess Beatrix locks as representative of domestic transport.
According to the CEMT table, the following vertical clearances apply to container ships (table 1, righthand column):

- 5.25 m for ships with 2 layers of containers
- 7.00 m for ships with 3 layers of containers
- 9.10 m for ships with 4 layers of containers.

The 9.1 m clearance is equivalent to the bridge height on the river Rhine, whereby 50% of containers are assumed to be empty. The real figure is lower, as can be seen in table 4. Nor does this take any account of high cube containers, which are taller than the standard 8½-foot-high container. Containers are a standard 20 foot (= 6.095 m) or 40 foot (= 12.200 m) long. Only 1% to 2% of containers are currently 35 or 45 foot long, but this might increase. The standard height is 8’6” (= 2.591 m), the width 8’ (= 2.438 m). However, taller high cube containers are becoming more and more common. Almost all high cube containers are 40 foot long. Pallet wide containers with an external width of 2.5 m have also been introduced. They are more suitable for loading with pallets. A standard 40-foot container can carry 25 1.2 x 0.8 m pallets; a pallet wide container of the same length can carry 30 pallets, representing a 20% gain. A 45-foot pallet wide high cube container can carry as many as 33 pallets.

Inland navigation vessels, with their rectangular holds, are perfect for transporting containers. No guidance structures are needed, though some vessels are equipped with them to speed up the loading process. The main difference between container ships and normal cargo ships is the option of raising the wheelhouse, so it is possible to see over the load, though cameras are usually also used. Positioning the wheelhouse on the bow of the ship is not a popular idea among bargemen. Table 3 shows the external dimensions and container capacity of several types of vessel. The Neokemp has been specially developed to transport containers on small

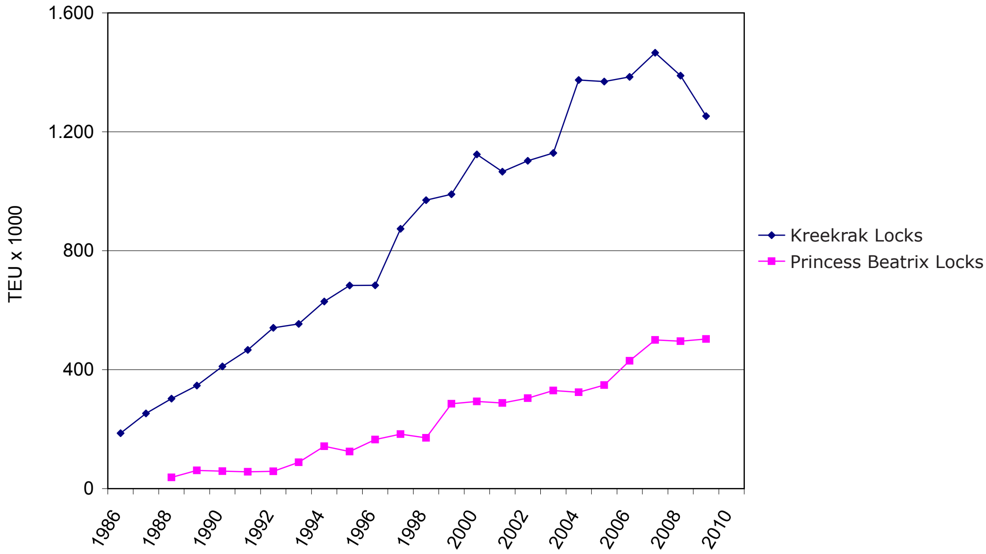


Figure 2: Development of container transport by water

waterways, particularly the canals of Brabant. The Jowi is 135 m long, the maximum length currently permitted on the Rhine. The last few years have seen the advent of coupled ships and barges, motorised vessels with their own push barge, specially designed for container transport.

type of vessel	**dimensions (m)** **length x width**	**capacity (TEU)** **width x height x length**
CEMT II	55.0 x 6.6	2 x 2 x 6 = 24
Neokemp	63.0 x 7.0	2 x 3 x 8 = 48
CEMT IVa	80.0 x 9.5	3 x 3 x 10 = 90
CEMT Va	110.0 x 11.4	4 x 4 x 13 = 208
CEMT VIa (Jowi)	135.0 x 17.0	6 x 4 x 17 = 398
Europa IIa push barge	76.5 x 11.4	4 x 4 x 10 = 160

Table 3: Vessel dimensions and container capacity

Table 4 lists some features of container transport on the Rhine, taken from surveys conducted in 1996, 2001 and 2006. Some things stand out immediately. The capacity of container ships on the Rhine is growing steadily, for example. The average vessel is now larger than Class Va.
Since container ships generally run a scheduled service, they cannot always wait until they are fully loaded. An average of 61% of capacity is used; in other words, the capacity utilisation rate is 61%. There is a large imbalance between the loads carried up and down the river. In 2006, an average 56% capacity was used on vessels travelling upriver to Germany, while 87% was used downriver, towards the sea.

The cargo weight in the loaded containers also differs sharply depending on the direction: downriver, containers carry much heavier loads than they do upriver. The explanation is simple: raw materials are generally transported to Germany as bulk goods, so they are not carried in containers; the completed products are exported in containers via Rotterdam and other sea ports to their destinations overseas.

20 Class VIa container ship (Jowi class), capacity 398 TEU

In the ten years since the first survey in 1996, the proportion of 40-foot containers rose from 45% to 66%, and the proportion of high cubes from 7% to 31%. Pallet wide and 45-foot containers are hesitantly beginning to make an appearance. These trends are expected to continue.

property	**1996**	**2001**	**2006**
average carrying capacity (survey data)	185 TEU	273 TEU	310 TEU
average number of containers (survey)	122 TEU	165 TEU	188 TEU
average load factor	66%	61%	61%
proportion of containers loaded	73%	67%	70%
- upriver	59%	49%	56%
- downriver	88%	86%	87%
average weight of all loaded containers*	12.4 t/TEU	12.7 t/TEU	11.4 t/TEU
- upriver*	12.1 t/TEU	11.6 t/TEU	10.6 t/TEU
- downriver*	13.7 t/TEU	13.8 t/TEU	12.4 t/TEU
proportion of 20-foot containers	55%	31%	32%
proportion of 40-foot containers	45%	68%	66%
proportion of 45-foot containers	0%	1%	2%
proportion of high cube containers	7%	18%	31%
proportion of pallet wide containers	0%	0%	3%

* incl. weight of empty container; percentages refer to proportion of TEU
Table 4: Properties of container transport on the Rhine

A standard 20-foot container weighs 2.08 tonnes and a 40-footer weighs 3.15 tons. The weight of the empty container is therefore an average 2.9 tons/TEU, so the weight of the container's load comes to an average of 8.5 tons/TEU. The average container ship in the 2006 survey, loaded with 188 TEU, therefore transported 188 x 8.5 x 0.7 = 1120 tons of useful load per trip. Add to this 188 x 2.9 = 545 tons, which is the weight of the containers themselves, and the total comes to 1665 tons.

The container is packaging for the shipper, but for the vessel it is part of the cargo weight. Table 4 shows incontrovertibly that inland navigation is not mainly about transporting empty containers, as a persistent myth would have us believe. On the contrary, a majority of containers (70%) are loaded. Nor is it the case that containers are transported only over large distances; domestic transport by waterway also occurs on a large scale. The latest inland terminal to be built is in Alphen aan de Rijn.

21 Alphen aan de Rijn container terminal, opened on 1 October 2010

3.7 Scale expansion

There is a trend towards ever larger vessels in inland navigation. Figure 3 shows that the average size of the vessels passing through three particular locks each year is on the increase. The Volkerak Locks are on the Scheldt-Rhine Canal, a Class VI waterway; the Princess Beatrix Locks are in the Lek Canal, a Class V waterway; the Princess Margriet Locks are in the Class IV waterway of the same name; and Lobith is on the Rhine. The almost constant upward curve for all waterway classes is particularly interesting: between 1970 and 2005 the average vessel size rose in all cases by a factor of approximately 2.5.

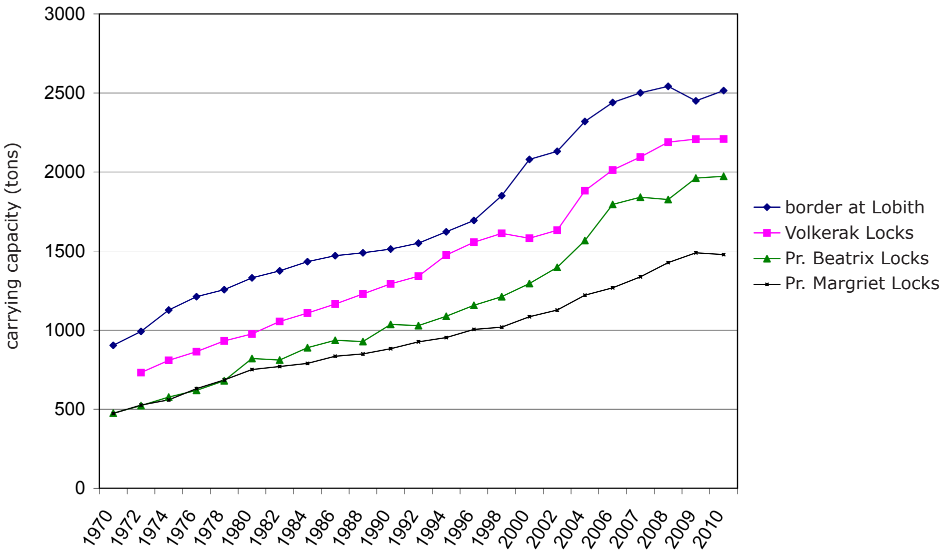


Figure 3: Average vessel size

This increase has been possible only because the vessels have been steadily increasing in size, as a result of two opposing trends: the number of ships in the active fleet sailing under the Dutch flag has gradually fallen, while the total carrying capacity has not followed the same trend, or at least not to the same extent. It has been mainly vessels with a tonnage below 1500 tons that have disappeared (figure 4). At the same time, the number of large vessels in Classes V and VI has increased. The average tonnage of the 112 cargo vessels added to the West European fleet in 2007 was 3405 tons. This is the same as a Class Va vessel measuring 110 x 11.45 x 3.65 m. Of those 112 vessels, 32% have a tonnage less than 3000 tons, 47% are in the 3000 to 4000 ton class, and 21% are larger than 4000 tons. The largest vessel in 2010 was a tanker with 16,000 tons carrying capacity, measuring 150 x 22.8 x 4.0 m. The majority of new vessels sail under the Dutch flag. This expansion in scale is undoubtedly set to continue for some time.

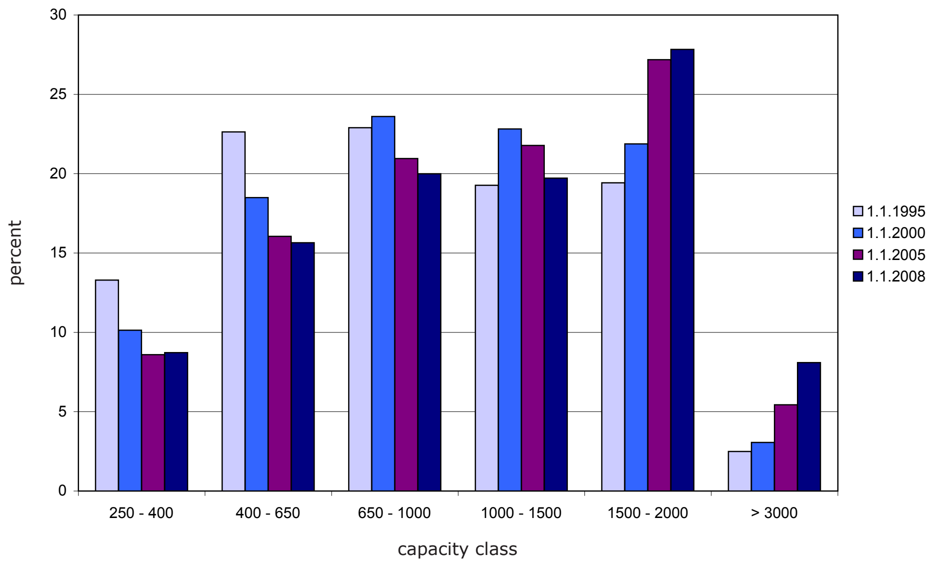


Figure 4: Composition of the Dutch active fleet

At the same time, there is a trend towards more specialised vessels, i.e. ships suitable for a particular sort of cargo: edible oils, cement, liquid gas, rolling cargo, palleted goods etc. The drawback is that vessels such as these are generally very expensive, can only transport that one particular kind of cargo, and seldom or never carry a return load. One special category is vessels that transport hazardous substances, which are obliged to carry one, two or three blue cones, by night blue lights. Vessels that carry such substances must have a double skin hull for safety in the event of a collision. In anticipation of more stringent official requirements, the Dutch tanker fleet now largely consists of double skin tankers.

CEMT class	**type**	**width (m)**	**length (m)**	**draft (m)**		**capacity (tons)**	**engine cap. (kW)**
				loaded	*empty*		
I	Spits	5.05	38.5	2.5	1.2	375	175
II	Kempenaar	6.6	50-55	2.6	1.4	550-615	240-300
III	Dortmund-Eems	8.2	67-85	2.7	1.5	910-1250	490-640
IV	Rhine-Herne	9.5	80-105	3.0	1.6	1370-2050	750-1070
Va	Large Rhine	11.4	110-135	3.5	1.8	3000-3750	1375-1745
VIa	Rhinemax	17.0	135	4.0	2.0	6000	2400

Table 5: Characteristics of standard motorised cargo vessels

Scale expansion can occur in two ways: by extending vessels, or building larger vessels. The first of these has happened on a fairly large scale, as Class II and IV vessels have been lengthened. It is a relatively simple matter to add on a new section of hold. The vessel might then have a Class III width, for example, and a Class IV length. The CEMT is no longer appropriate for the situation in the Netherlands, therefore. Tables 5 and 6 are based on an analysis of the Dutch active fleet. The principle on which the identification of the standard draft in table 5 is based is the average maximum draft of the standard – and therefore largest – vessels for the waterway in question. The actual maximum draft of the vessels is some 0.2 m greater. Vessels are by no means always fully loaded because of draft restrictions on other navigation routes, transport of goods with a low volume weight, or consignments smaller than the capacity of the vessel. Table 6 shows the Class characteristics. They refer to all vessels in the class, not only the standard vessels. The lowest ship height is defined as the height not exceeded by 90% of empty ships in a particular class.

CEMT class	**lowest ship height 90% (m)**	**average engine capacity (kW)**	**average bow thruster capacity (kW)**
I	4.65	175	100
II	5.8	250	130
III	6.3	435	160-210
IV	6.7	690	250
Va	7.1	1425	435-705
VIa	10.0	2015	1135

Table 6: Class characteristics of motorised vessels

3.8 Recreational navigation

Recreational navigation has always existed. For a long time, however, it was the preserve of the wealthy, and was therefore practised only on a small scale. But the increase in prosperity after the war brought about a rapid growth in recreational navigation, particularly from the 1960s and 70s onwards. Now, the sector is not only economically important, in the sailing season pleasure craft account for a significant proportion of traffic on the waterways. Figure 5 shows that at some locks the number of pleasure craft far exceeds the number of commercial vessels.

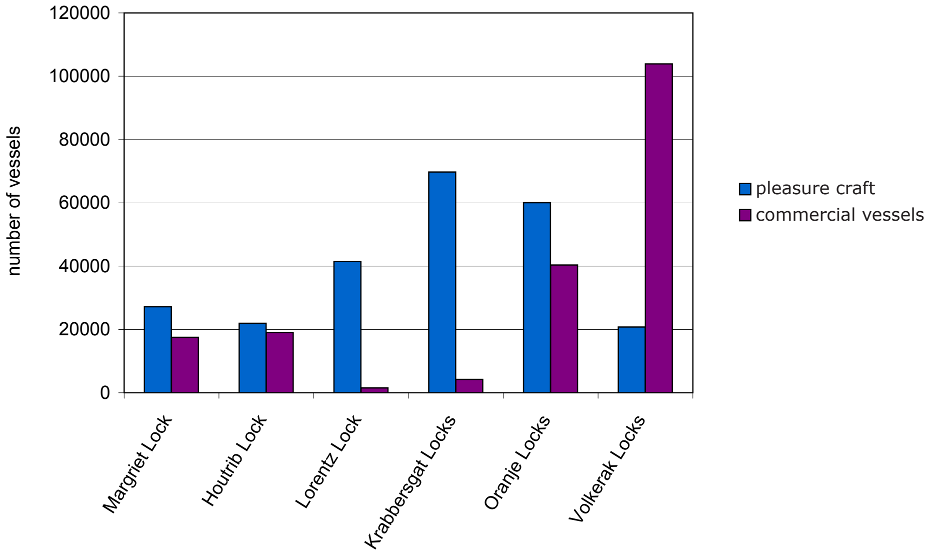


Figure [illegible]: Number of pleasure craft and commercial vessels in [illegible]

Besides the main waterway network, there is also a network for recreational touring. In 2008 the national association for recreational touring published a policy document setting out a vision for recreational touring in the Netherlands, known as BRTN 2008. The aim of the BRTN is to achieve a greater degree of consistency in the touring network, in terms both of dimensions, and of the operating hours of locks and bridges. The policy document focuses on touring, i.e. sailing and motor boats with accommodation, so passengers can sleep on board during tours lasting several days. In practical terms, these tend to be motorised saloon boats over approx. 6 m long. The authors of the BRTN have drawn up a classification for the navigable waters, linked to standards for drafts and heights, since there are in fact no standards types of vessel in recreational navigation. The BRTN includes the following waterway classes:

- connective waterways: connect the major sailing areas (A)
- access waterways: provide access to individual sailing areas (B, C and D)

B, C and D indicate gradations. Each class has been differentiated into waters accessible to sailing and motorised craft (ZM) and those that are only accessible to motorised and sailing craft with a lowered mast (M).

ZM route		**length**	**width**	**draft**	**boat height and bridge clearance**	
connective waterway	A	15.0	4.5	2.10	30.0	
access waterway	B	15.0	4.5	1.90	30.0	
M route		length	width	draft	boat height	bridge cl.
connective waterway	A	15.0	4.5	1.50	3.40	3.75
access waterway	B	15.0	4.5	1.50	2.75	3.00
	C	14.0	4.25	1.40	2.75	3.00
	D	12.0	3.75	1.10	2.75	2.60

Table 7: Standard boat dimensions (m) for Z and M routes, according to the BRTN 2000

For M routes, the bridge height plus a safety margin is given. The vast majority of craft (80% to 90%) comply with the values listed in table 7. Since the average dimensions of the recreational fleet are increasing, it is recommended that the standard dimensions in the table be regarded as an absolute minimum, however. Where dimensions larger than the standard measurements are permitted, the principle is 'preserve what you have'.
The United Nations' Economic Commission for Europe set out dimensions for a European network of recreational waterways in 2004. These are listed in table 8. They differ slightly from the BRTN. It is therefore wise to take them into account, particularly as regards bridge clearance.

type of craft	**category**	**length**	**width**	**draft**	**bridge clearance**
open boat	RA	5.5	2.0	0.50	2.00
saloon boat	RB	9.5	3.0	1.00	3.25
motor yacht	RC	15.0	4.0	1.50	4.00
large sailing yacht	RD	15.0	4.0	2.10	30.00

Table 8: Standard craft dimensions (m) according to ECE 2004

One special category of recreational navigation is charter boat navigation: former commercial sailing vessels that are rented out, with or without a professional crew, to paying passengers. The common name – the 'brown fleet' – refers to their faded brown sails. Charter boat navigation must be regarded as commercial navigation for recreational purposes, not as recreational navigation. It is particularly common on major waters and waterways, like the Waddenzee, the IJsselmeer and in the Delta area. In table 9, class BVA is the standard for large open waters. Class BVB represents charter boats with the exception of large craft, and is regarded as the standard for sheltered waters. The width is the measurement of the hull including lee boards, for which 0.25 m is added on either side of the hull, so an additional 0.5 m in total.

class	**length**	**width incl. leeboards**	**draft**	**boat height and bridge clearance**
BVA	35.0	7.0	1.4	30.0
BVB	25.0	6.0	1.2	30.0

Table 9: Standard dimensions (m) for charter boats

Besides recreational touring and charter boat navigation, there is a further category covering 'small-scale water sports' like rowing, canoeing, surfing etc. These generally occur on lakes or in the immediate vicinity of a marina. Waterways for small-scale water sports also generally host other kinds of water-based recreation, such as swimming, fishing or skating. In the dimensions of small waterways, it is wise to take account of the requirements for small-scale water sports, even if no commercial or recreational navigation is expected. Table 10 gives measurements for the depth of the waterway, the width, and bridge clearance. The Water Sports Council presented a policy vision in 2001 calling for a national network for small-scale water sports.

22 Motor cruiser on the river Vecht, an AZM route

depth of waterway	**description of use**
1.0 1.2 1.5	navigable for canoeing, tour rowing and windsurfing minimum depth for small dredgers fishing
bridge width	**description of use**
2.5 4.0 5.0 6.0	normal width for canoes normal width for small dredgers windsurfing normal width for tour rowing
bridge clearance	**description of use**
1.25 2.5	minimum for canoeing, rowing and small dredgers minimum for tour skating and windsurfing

Table 10: Waterway dimensions (m) for small-scale water sports

The recreational fleet is also experiencing an increase in the size of craft. Height is particularly important, since this determines how often bridges need to be opened. Figure 6 shows the results of measurements taken at Terherne on Sneekermeer lake in the heart of the Frisian water sports area. Virtually 100% of motorboats were less than 3.4 m high in 1986, requiring a bridge clearance of 3.75 m. By 2001, the figure had fallen to 70%, so 30% of motorboats were taller than 3.4 m. The link for sailing craft was less clear at Terherne. It might be that larger boats tend to head for larger bodies of water, but it could also be that more sailing boats (chartered or otherwise) passed that spot. Figure 6 suggests that the effects of scale expansion may have an impact in the near future.

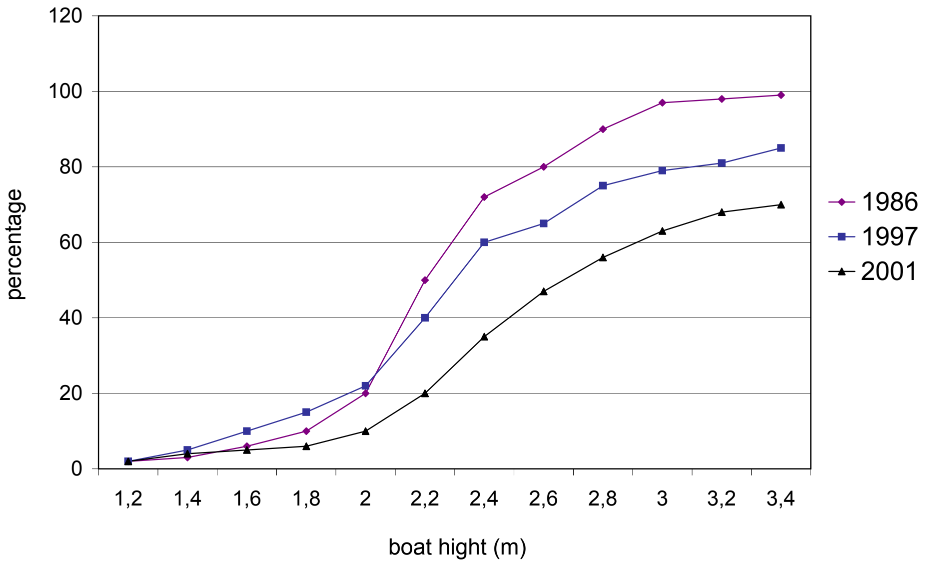


Figure 6: Curves showing proportion of craft below certain height at Terherne, Friesland

3.9 Inland navigation vessels in a nutshell

This description of the development of inland navigation vessels has shown the following:

- inland navigation vessels are most suited to bulk transport
- container transport is also bulk transport these days
- the advent of the internal combustion engine and radar made inland navigation vessels an extremely efficient mode of transport
- the average vessel size has grown enormously over the years, and there is no prospect of an end to this trend
- due to scale expansion, the CEMT table is no longer appropriate for the Netherlands
- recreational navigation accounts for a large proportion of traffic on many waterways
- recreational craft are also growing in size, particularly in terms of their height

Illustrations

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Augustus 2011 | DVS0811RE142